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STUDY OF MODIFICATION IN THE EFFICIENCY OF SOLAR CELL

Mukul Kant Sharma[*1], Deepak Tanwar[2] and Prof. Vikram Singh
B.Tech, 4th year[1,2] Asst. Prof. Applied Science[3]
Sunder deep college of Engg. & Tech., Ghaziabad
msmukul.sharma@live.com[*1], tanwardeepak011@gmail.com[2], vickychouchan21@gmail.com[3]

Abstract: The energy economy of nearly all end, In particular of industrialized countries is based on the use of stored energy, mainly fossil fuels in the form of coal, oil, natural gas, as well as nuclear energy in the form of uranium isotopes. Two problems arise when we use our reserves to satisfy our energy needs. A source of energy can continued only until it is depleted. Furthermore, burning these fossil fuels also has hazardous effects on our atmosphere. These sources are also known as non renewable sources. So these are not available for always.

So the alternative for these non renewable sources are use of renewable energy sources like sun energy, wind energy etc. In this Paper we discuss about study of best utilization of solar energy in the form electricity by studying photovoltaic material. In this paper we study several technologies of solar cell and their conversion efficiency level.

INTRODUCTION

When one thinks of all the technological advances over the past century, space travel, plastics, supercomputers, and genetic engineering to name a few, it is a bit odd to think that the energy used to do or make those things essentially come from burning stuff. While we are a few levels above cavemen burning wood for warmth that is essentially what we are doing. Eighty-five percent of US energy consumption comes from burning fossil fuels: coal, petroleum, and natural gas. [1] The attraction of fossil fuels lies in their familiarity and their availability. Because we have been using them since the start of the Industrial Revolution, fossil fuels are a very mature technology. And while petroleum can be a bit of a problem, the US has over two hundred years worth of coal reserves (based on current consumption) and it can be had for dirt cheap.[2] .

The average efficiency of American coal power plants is around 37%, though new plants that use the latest technology can approach 50% efficiency.[3] Ultimately these sources will be limited by the second law of thermodynamics to below 70% efficiency, though combined cycle plants that produce Electricity and heat can get up to 80% and beyond. Relying on fossil fuels has served us reasonably well up until this point, but that era has now come to an end because of global climate change. It turns out that by burning all those carbon containing compounds that were trapped under the Earth's surface for millennia we are releasing CO_2 into the atmosphere, thereby strengthening the natural greenhouse effect that the atmosphere provides. The changes to the climate that are occurring due to this process are probably best avoided, which means that new sources of energy will have to be found that do not rely on burning carbon compounds.

Solar Energy:

Fortunately there exist many alternative forms of energy production that are both clean and renewable. They are "clean" in the sense that they don't emit CO2 or any other pollutant and "renewable" in the sense that they are not dependent on substances that take thousands or millions of years to form through natural processes. Such renewable energy sources include solar (both photovoltaic and solar thermal), wind, hydro, geothermal, tidal, and biofuels. Here we will just be focusing on solar energy in the form of photovoltaics. Light's ability to generate electric current was first observed in 1839 by A. E. Becquerel when he discovered the photo electrochemical process [4]. Then in 1906 anthracene became the first organic compound in which photoconductivity was observed. Photoconductivity of organic materials was studied in the 1950s with the aim of using them as photoreceptors. At about that same time inorganic materials entered the field when Bell Laboratories developed the first inorganic solar cell in 1954.

The photovoltaic effect was first observed in an organic material in the 1960s after it was discovered that some common dyes had semiconducting properties. A major breakthrough in the field came in 1986 when Tang discovered that the output power could be greatly increased if two materials were used instead of just one.[5] This concept, known as a hetero-junction, is now the fundamental idea behind the theory and design of organic photovoltaic's . One of the largest breakthroughs since that point was the creation of the first dye-sensitized solar cell by Michael Grätzel in 1991. Grätzel later improved his cell to be over 11% efficient, a huge jump over previous cells that had efficiencies of just 1% or less. The Grätzel cell is still the most efficient organic solar cell in the world. For comparison, silicon solar cells have efficiencies up to 20%, while the most advanced (and expensive) GaAs cells have gotten above 40%.

Solar Cell:

A solar cell or photovoltaic cell is a device which generates electricity directly from visible light by means of the photovoltaic effect. Photovoltaic is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current result that can be used as electricity.

The basic idea is that the atoms in a semiconductor placed in the sunlight will absorb photons from the sun's radiation. If these photons are of high enough energy, an electron in the valence band will use the absorbed energy to move up into the conduction band of the semiconductor, which allows it to move freely through the semiconductor to an electrical contact from where it is driven by a small voltage through wires as current. [6].The energy the electron needs to move from the valence band to the conduction band is called the band gap of the semiconductor. For this to work in an efficient manner there must be two kinds of semiconductor in the solar cell. One, the n-type semiconductor, is doped with impurities such that it has an excess of electrons.

The p-type semiconductor has a deficit of electrons, creating "holes" where it is missing electrons. When the two are placed in contact to create a p-n junction, electrons from the n-type semiconductor diffuse into the p-type semiconductor, leaving holes behind, until enough electrons accumulate on the p-type side of the boundary and enough holes accumulate on the n-type side of the boundary that an opposing electric field is created and equilibrium is reached. Photons are then absorbed within the p-type semiconductor, freeing electrons which will flow through the p-n junction to the electrical contact, while the hole goes the other way. (See Figure 1.1) The electric field at the junction is what drives the electrons around the circuit. The electron will travel into a circuit and do work before recombining with the hole.[7]

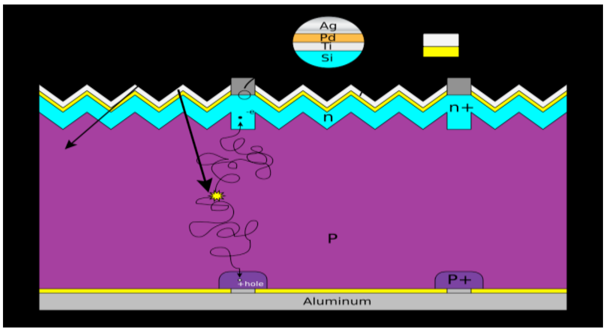


Figure 1.1: Incident light is absorbed by the solar cell (some is reflected) and generates an electron and a hole, which migrate to the cell's electrical contacts.

Nanotechnology:

Nanotechnology can be defined as the study of material and its properties at nano-scale. At nano-scale the properties of material changes and enhance the conduction properties of the material. Nanotechnology is the understanding and control of matter at dimensions of roughly 1-100 Nms, where unique phenomena enable novel applications. Manufactured products are made from atoms. The properties of these products depend on how the atoms are arranged. Nano Technology helps to snap together the fundamental building blocks of nature easily, inexpensively and in most of the ways permitted by the laws of physics. The strength and lightness of materials depends on the number and strength of the bonds that hold their atoms together. Besides light weight and great strength, carbon particles like diamond have a host of material properties that make it an excellent choice for NANOTECHNOLOGY.

Nanoelectronics:

When we use the nano-scaled material in manufacturing and fabrication of electronic materials, then such kind of technology is known as nano-electronics. Some of the nano-electronic materials are bulky balls, nano tubes, nano wires etc. Buckyballs are soccer-ball-shaped carbon molecules are roughly 1 nm in diameter. Carbon nano-tubes are about 1.4 nm thick. Nano-scale lithium particles could store higher energy densities.

TYPES OF SOLAR CELL AND THEIR PROPERTIES

In modern time researchers and scientists are working on different types of materials to introduce a cheap and best solar cell for the future. Some of the different types of solar cell which are made using different methods and materials are described in this section.

Crystalline Silicon Cells:

These conventional cells are generally made from layers of silicon a few hundred Micrometers in thickness. Silicon for bulk cells is refined and grown into lightly p-type Doped crystalline ingots that are then sliced into extremely thin wafers. However, the Size that the crystalline wafers can be cut to is still very thick when compared to thin film Solar cells, and when considering the vast areas the wafers must cover it adds up to a Highly intensive use of silicon. To make the wafers into solar cells, n-type dopants (often Phosphorous) are diffused across the surface, creating the p-n junction. The vast majority of solar cells sold commercially are crystalline silicon cells. As the second most abundant element on Earth, silicon is an almost inexhaustible resource. For the past couple of years the industry has been facing a shortage of refined silicon due to growing demand that has kept the price of silicon solar cells from decreasing at their normal rate.

Mono-crystalline Silicon Cells:

Mono-crystalline cells are made from a single large crystal wafer of silicon. These cells have high efficiency, but are expensive due to the demanding production process.

Poly-crystalline Silicon Cells:

Less expensive than mono-crystalline cells, poly-crystalline cells are also less efficient. The method of casting a poly-crystalline wafer of silicon as opposed to a mono-crystalline wafer requires much less precision and expense.

Thin Film Technologies:

In order to counter the processing, materials, and handling costs associated with Crystalline silicon cells, much research has gone into perfecting methods of making solar cells with semiconductors only a few micrometers in thickness. The hope is that these cells will be able to achieve reasonable efficiency while using very little silicon and employing roll-to-roll processing. These cells have lower efficiency than crystalline silicon cells but frequently have costs that are low enough to make them competitive.

Amorphous Silicon Cells:

Amorphous silicon ("a-Si")-the non-crystalline form of silicon - can be deposited onto a conductive substrate in a layer a few micrometers thick to create a thin film solar cell. The deposition process of applying a-Si allows it to be less than 1% of the thickness of a crystalline cell. [7, 8] Typically alloys of a-Si and germanium are used to create the additional junctions in the multi-junction cells. These cells are lighter, use much less material and are less energy intensive to produce than bulk silicon cells. However, the cell efficiency of amorphous silicon is much lower than crystalline silicon due largely to the increased recombination of the electron-hole pairs that results from the lower carrier mobility. [9]

Cadmium-Telluride Cells:

The crystalline compound cadmium-telluride (CdTe) is an effective solar cell material – it's a very strong absorber of light and has a band gap almost perfectly tuned to match the solar spectrum. To create a p-n junction for solar cells a layer of cadmium sulfide is added to the CdTe. Because of its effectiveness a CdTe solar cell uses only about 1% of the semiconductor material that bulk silicon cells use[10]. CdTe solar cells are generally somewhat less efficient than bulk silicon cells, but have lower costs associated with them due to the smaller amount of material used and inexpensive production methods. While sales of low-priced CdTe cells have sharply increased, the soaring consumption of the very rare metal tellurium has pushed the price of that element up sharply[10]. It remains to be seen how the production of CdTe solar cells will be affected in the future by supply constraints. CdTe is a toxic carcinogen and some concerns have been raised about the danger of solar cells made with CdTe. These concerns have been countered by noting that the Cadmium contained in one square meter of a CdTe cell is less than that within a size-Cindy flashlight battery and that the CdTe is very well sequestered by the encapsulation of the cell [11].

Copper-Indium/Gallium-DiSelenide Cells:

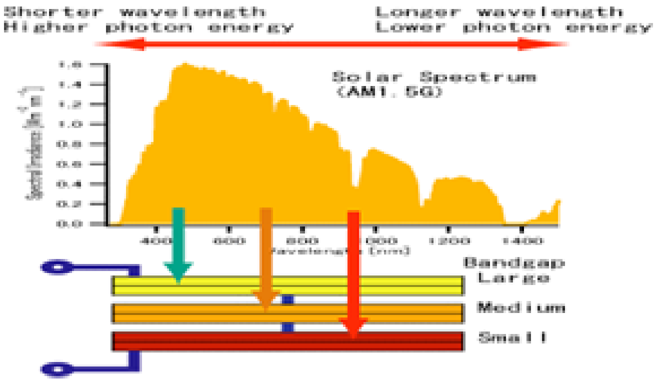
In one of the most immediately promising technologies, cells are made from combination of copper-indium-dieseline and copper-gallium-dieseline (CIGS cells)and have recently been shown to be up to 19.9% efficient,[12] the highest efficiency of thin-film cell.[13]The mixture of the two materials creates a more complex and effective "heterojunction," The band gap of Fig 2.1 Different wavelengths of the solar spectrum are absorbed by stacked cells with different band gap energies. (Image in public domain) the semiconductor in CIGS cells can be varied by altering the ratio of indium to gallium, allowing the band gap to range continuously from 1.0 eV to 1.7 eV in the cell, [14] which matches very well with the solar spectrum.

Multi-Junction Concentrators:

Multi-junction cells layer two or more p-n junctions which each have semiconductors with a band gap tuned to absorb a different portion of the solar spectrum. Photons will hit the top semiconductor - the one with the highest band gap energy - and if the photon energy is above that semiconductor's band gap energy, it will be absorbed and produce electricity. If the photon energy is too low, it will pass through the semiconductor to be absorbed by one of the lower semiconductors in the cell. Because the advanced engineering often required to craft multi-junction cells can create high costs, concentrators are used to gather sunlight from a wide area and focus it on a small solar cell, reducing the amount of photovoltaic needed. The concentrators are usually mirrors and lenses that track the sun and enhance the intensity of the light incident upon the photovoltaic cells to an intensity dozens of times higher than unconcentrated sunlight.

Gallium-Arsenide Cells:

A triple junction gallium-arsenide (GaAs) cell may use gallium-indium-phosphide(GaInP), gallium-arsenide, and germanium (Ge) p-n junctions. Combined with concentrators, these cells are by far the most efficient yet developed, achieving 40.7%efficiency in the laboratory.[15] Cells with efficiencies as high as 36% are currently commercially available.[16] Although GaAs cells are highly efficient, their high cost currently discourages their more widespread usage.



Emerging Photovoltaic Technologies:

There exists a wide variety of photovoltaic technologies in the research stages that have-not yet entered into common commercial production. These technologies are the subject of cutting-edge research at universities, government laboratories and start-up companies that are seeking photovoltaic cells that can be manufactured more efficiently, have greater quantum efficiencies than available technologies, and are composed of abundant on-toxic materials.

Organic Cells:

Organic cells function in a slightly different way than most other cell technologies: instead of semiconductor p-n junctions, organic cells utilize electron donor and acceptor materials. Typical choices are polymers for the electron donors and fullerenes for the electron acceptors. When an electron-hole pair is created by the absorption of a photon in the donor, rather than separating and migrating to opposite sides of the cell, the electron and hole stay together as an excitation. The excitation diffuses through the cell until it reaches the acceptor where the electron is transferred to the acceptor material, creating a current through the acceptor.

The benefit of using of organic materials is that it allows for the simple high volume low-temperature fabrication of flexible solar cells on plastic substrates. If the efficiency of the cells can be improved, organic cell technology will realize extremely low cost production of very versatile cells. Efficiencies of organic solar cells are currently around 5-6%, although quickly rising. Organic solar cells must also overcome the issue of environmental degradation, a problem that most organic molecules face when exposed to oxygen, water and solar radiation.

Dye-Sensitized Cells:

DSSCs are quite different in function from the other Photovoltaic technologies in existence and in fact bear a somewhat loose resemblance to photosynthesis. The material components of a DSSC are a thin film of electrolyte sandwiched between two electrodes (the top electrode being transparent to allow light into the cell) with a lattice of dye-coated nano-scale titanium-dioxide (TiO2) particles coating one of the electrodes. The DSSC works on the principle of splitting the functions performed by the semiconductor in other photovoltaic technologies. In a silicon cell, the silicon both generates the charge, and conducts the electrons and holes to the electrodes. In a DSSC, the incident photons excite electrons in the dye molecules. If given sufficient energy, the excited electrons will escape from the dye to the conduction band of the TiO2 Particles and will then diffuse to the electrode, generating a current. DSSCs do not have this problem of recombination (often a serious drag on the efficiency of solar Cells even during periods of high intensity light) due to the separation of the electron producer and the electron carrier, and can thus function robustly under limited light under cloudy skies, and even indoors. This property was recently exploited during an Antarctic expedition where DSSCs were used to provide a significant portion of the expedition's power under the extreme conditions [17].

THEORY

A solar cell is characterized on a basic level by the graph of its current as a function of voltage, known as its I-V curve. An example of such a graph is shown in figure 3.1. From this graph a few important performance parameters can be extracted, mainly the open circuit voltage, short circuit current, fill factor, and maximum power. Open circuit voltage is the voltage the cell produces when it is sourcing no current and represents the maximum voltage of the cell. The short circuit current is the current the cell can produce when the two electrodes are shorted together (i.e. V = 0). Because power is the product of voltage and current, the point on the graph that forms the largest rectangle with the two axes represents the point of maximum power output.

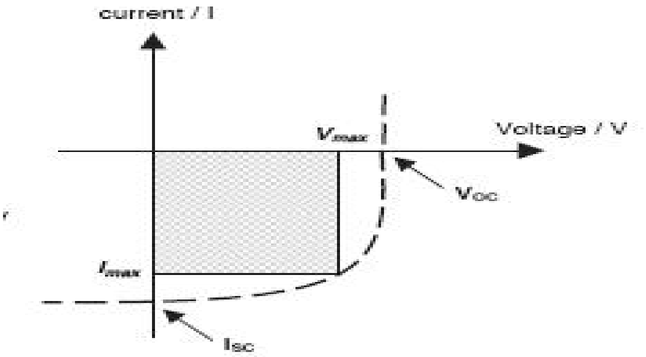


Figure 3.1: An example of a current-voltage graph.[4]

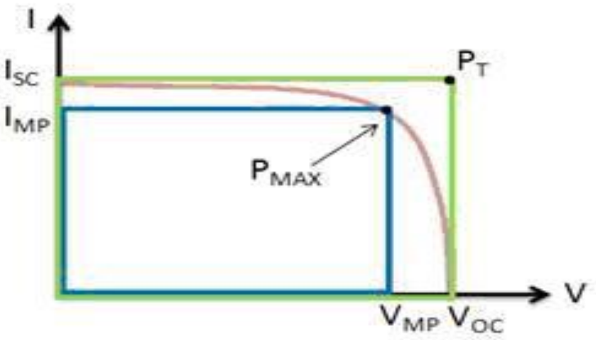


Figure 3.2: An illustration of the maximum power point and fill factor.[18]

Fill factor is just the ratio of the actual maximum power to the ideal maximum power, that is

$$P_{max}/P_t = (V_{mp}*I_{mp})/(V_{oc}*I_{sc}) \qquad (2.1)$$

The source of the name should be apparent from the visual representation shown in figure 3.2. From this point it is straightforward to get the power conversion efficiency, just divide the maximum power output by the power of the incident light:

$$e = P_{MAX}/P_{IN} \qquad (2.2)$$

A few more characterization parameters can be found by modeling a solar cell as a current source in parallel with a diode with two resistive elements, as shown in figure 3.3. R*S* is the series resistance while R*SH* is the shunt resistance.

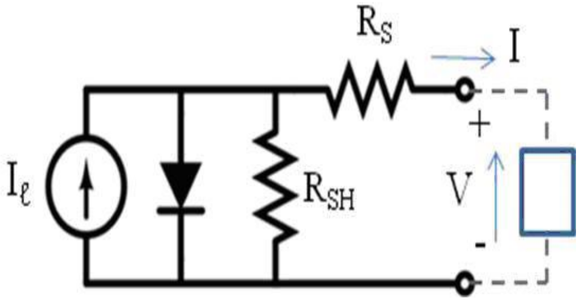


Figure 3.3: This circuit is a model for a solar cell. [18]

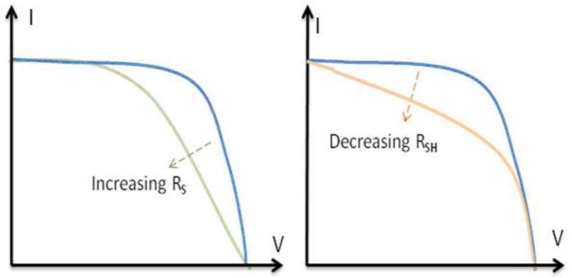


Figure 3.4: An illustration of R*S* and R*SH*[18].

The effects of these two non-idealities are shown in figure 3.4. So the current delivered to the load becomes that of the current source (from the photovoltaic effect) minus the losses from the diode and the resisters,

$$I= I_t - I_o\ (e(q(V+IR_s)/nKT) - 1\ ) - ((v+IR_s)/R_{sh}) \qquad (2.3)$$

Where *I*0 is the reverse bias saturation current, *q* is the charge of the electron, *n* is the ideality factor of the diode, *k* is Boltzmann's constant, and *T* is temperature.

CURRENT RESEARCH

Researchers at the University of California, Los Angeles have developed a new kind of polymer solar cells that are 70% transparent to human vision and have 4% power conversion efficiency. The lightweight, flexible cells can be produced in bulk at a low cost, and could be used to create power generating windows.[19]Additional research has been conducted on creating SWNT hybrid solar panels to increase the efficiency further. These hybrids are created by combining SWNT's with photo excitable electron donors to increase the number of electrons generated. It has been found that the interaction between the photo excited layer and SWNT generates electro-hole pairs at the SWNT surfaces. This phenomenon has been observed experimentally, and contributes practically to an increase in efficiency up to 8.5%.[20]Other research for designing solar cell is to use Quantum dots. The quantum dot using *InAs/GaAs* system can generate the 25 % efficiency and it may be increased[21]. Band gap engineering of silicon nanostructure can also improve the efficiency of solar cell. Work in the field of Band gap improvement is also the current research topic.[22]

Table: 1 Current Solarcells And Their Effyciencies:

S. NO.	TECHNOLOGY	PHOTOVOLATIC DEVICE	EFFICIENCY
1.	Monocrystalline solar Cells	Silicon solar cells	24.7% lab efficiency[23]; 20.1% commercial module efficiency[24]
		Galium arsenide (GaAs)	25.1% lab efficiency[25]
2.	Thin-film technologies	Thin-film silicon (TFSi)	9.5% (a-Si)[26]; 12% (tandem a-Si/^{1}c-Si)[27]; 13% (triple junction using SiGe alloys)[28]. All these are lab efficiencies
		Cu(In, Ga)(S, Se)2 and relatedI-III-VI compounds (CIGS)	19.9% lab efficiency[29] 13.4% commercial module efficiency[30]
		Cadmium telluride (CdTe)	16.5% lab efficiency[31] 10.7% commercial module efficiency[32]
		GaAs	24.5% [33]
3.	Organic-based solar Cells	Bulk-hetero-junction solar cells	6.5% lab efficiency [34]
		Dye-Sensitized cell (Graetzel cell)	10.4% laboratory efficiency[35]
4.	Novel PV technologies: Novel active layers	Quantum wells, Quantum wires, Quantum dots, Nanoparticle inclusion in host semiconductor	Theoretical efficiency limits are 50-60% [36,37]
5.	Novel PV technologies: Boosting the structure at the periphery of the device	Up-down converters	>10% efficiency improvement relative to baseline should be demonstrated in the coming decade
		Exploitation of plasmonic Effects	>10% efficiency improvement relative to baseline should be demonstrated in the coming decade
6.	Concentrator photovoltaic Technologies(CPV)	Si concentrator cells, III-V multi-junction cells	Laboratory efficiencies: 26.8% @ 96 suns (Si cells) [38]; 40.7% @ 240 suns (III-V cells) [39]

RESULTS AND ANALYSIS

In this work we have studied various types of organic materials for solar cell.Plastic solar cells offer the prospect of flexible, lightweight, lower cost of manufacturing, and hopefully an efficient way to produce electricity from sunlight. Since the discovery of photo induced charge transfer from a conjugated polymer to C$_{60}$, followed by introduction of the bulk heterojunction concept, this material combination has been extensively studied in organic solar cells leading to a power conversion efficiency approaching 6% nowadays. The photoactive layer is based on a blend of anelectron donating material (*p*-type semiconductor) and an electron accepting material (*n*-type semiconductor) forming nanostructured by continuous interpenetrating networks.In our analysis, we study different materials by reading different papers published. The most commonly used solar cells are silicon solar cell and galium arsenide solar cell having the having the maximum conversion efficiency of 24.7 % and 20.1 % respectively. These are cheaper solar cells in the market. Thin film technologies like thin film silicon cell Cu(In,Ga)(S,Se)$_2$ and cadmium telluride having efficiency range lies between 16.5 % to 25 % in laboratories and 9.5 % to 19.9 % in market.Organic based solar cells like bulk-hetrojunction solar cells and dye sensitized cells have the efficiency of 6.5 % to 10.4 %. Novel PV technologies like Quantum wells, Quantum wires, Quantum Dots, Nano-particle inclusion in Host semiconductor have the efficiency of 50 % to 60 % in labs.

CONCLUSION

By studying some thesis we conclude that Novel PV technologies like Quantum wells , Quantum wires, Quantum Dots, Nano-particle inclusion in Host semiconductor have the maximum conversion efficiency upto 60 % but this technology is very costly and thus to provide it in open market we need to reduce its cost. On the other hand organic solar cells are cheaper and can be printed in the cloths but they have very less efficiency. So we can improve the efficiency of organic solar cells by using nano-electronics and other some other methods of synthesizing PV materials.

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